Damage rheology applied to ice stream margin dynamics

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Why damage mechanics?

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Crevasses photographed on Byrd's polar flight.

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- contains feedbacks that lead to failure processes
- can lead to oscillatory behaviour

Mathematical formulation

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- Damage evolution law (viscous):

$$\frac{d\omega}{dt} = F_{\mathrm{v}isc}(J_1, J_2, \omega)$$

Elastic damage law

Damage evolution law (Lyakhovsky et al., 1997)

$$\frac{d\omega}{dt} = C_d I_2 (\xi - \xi_0).$$

I_1 and I_2 are invariants of the strain tensor, and the deformation state is

$$\xi = \frac{I_1}{I_2}, \qquad \xi_0 < 0.$$

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Damage affects the elastic moduli

$$\lambda = \lambda_0 \; (+ \ldots), \qquad \mu = \mu_0 + \omega \xi_0 \gamma_r$$

Motion events

(A) Basic decoupling

Elasic relaxation

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(B) Damage increase

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(B) Damage increase

(C) Failure at margin

Motion events

(A) Basic decoupling

Elasic relaxation

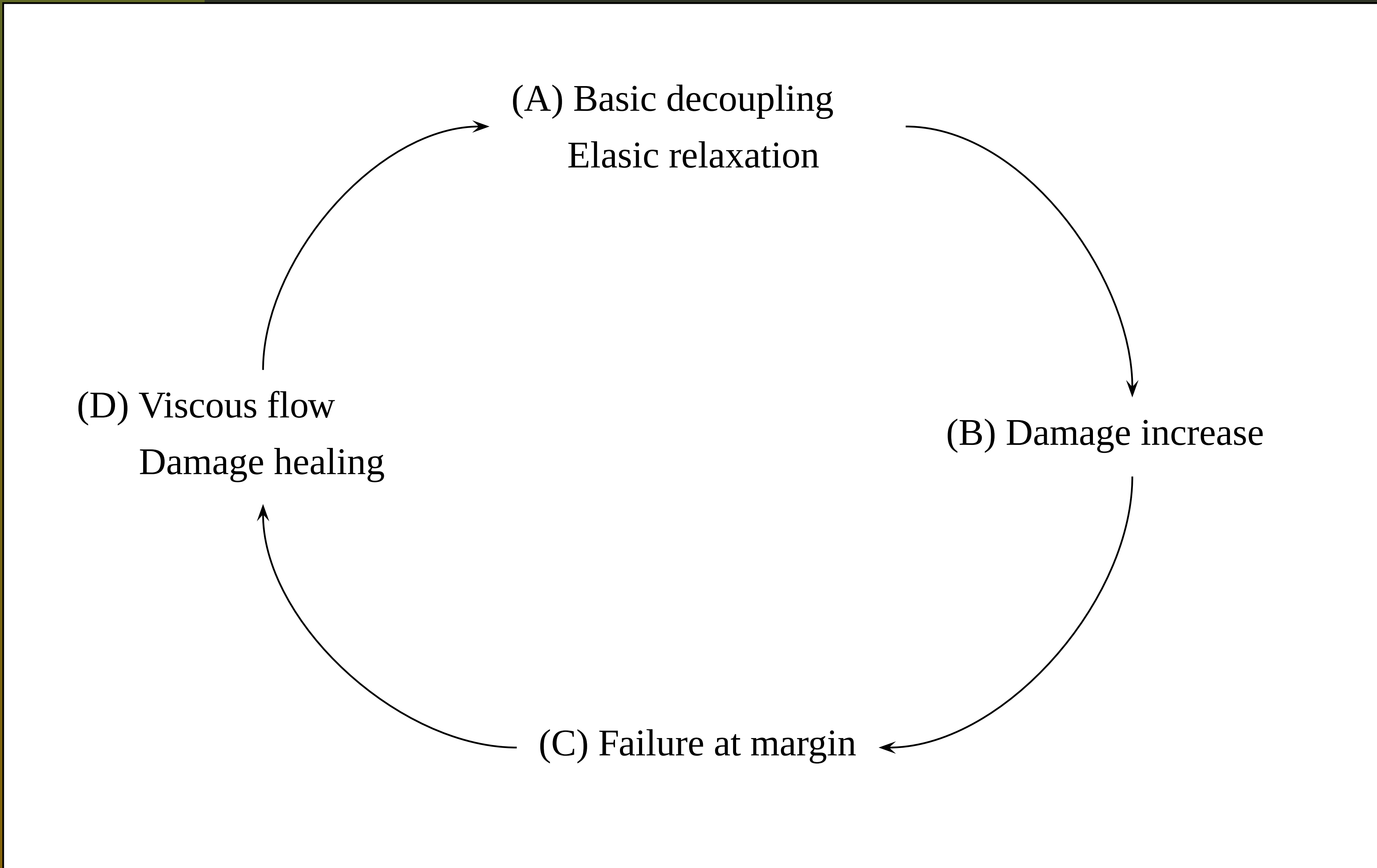
(D) Viscous flow

Damage healing

(B) Damage increase

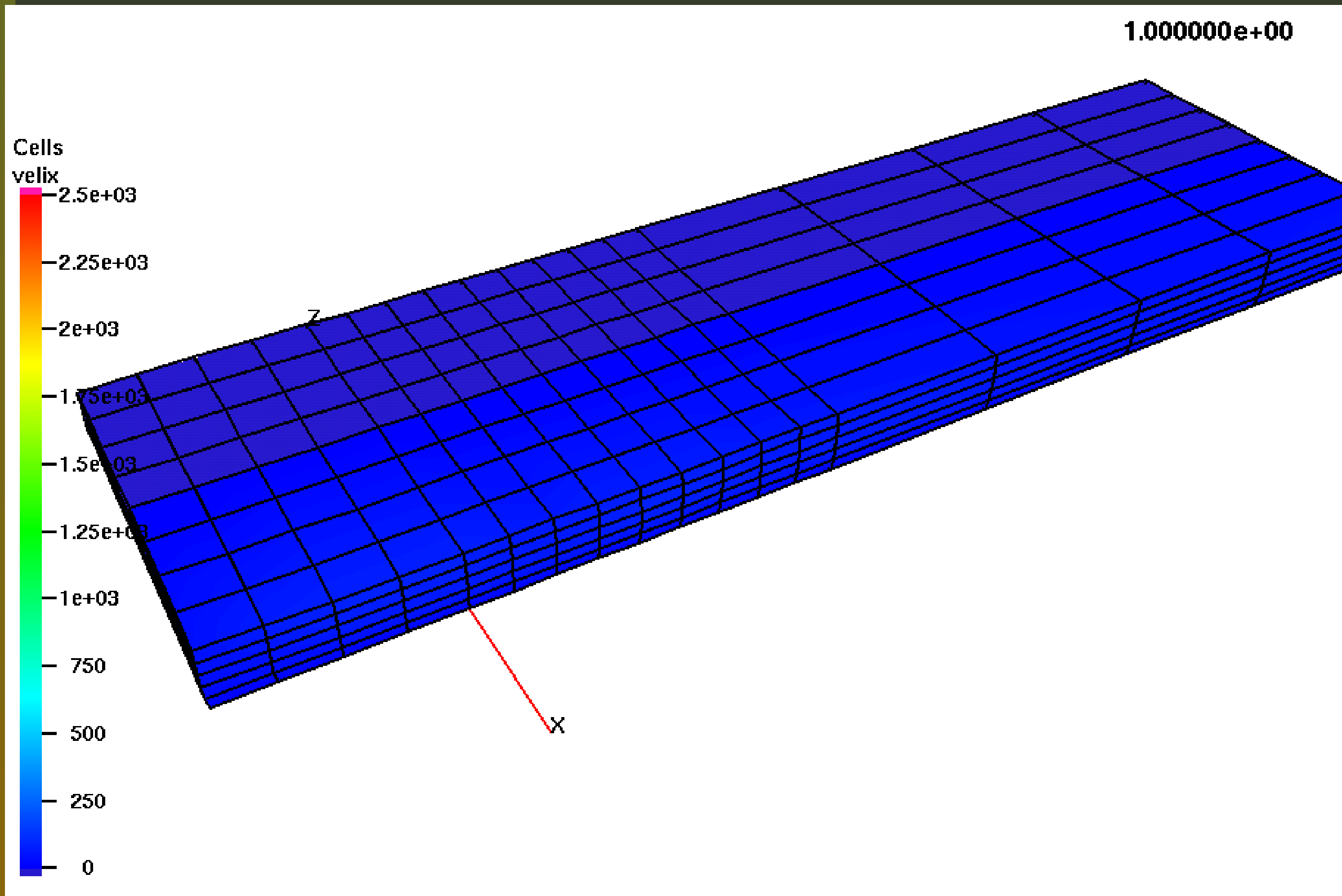
(C) Failure at margin

Motion events



Motion events

(A) Elastic relaxation:



Motion events

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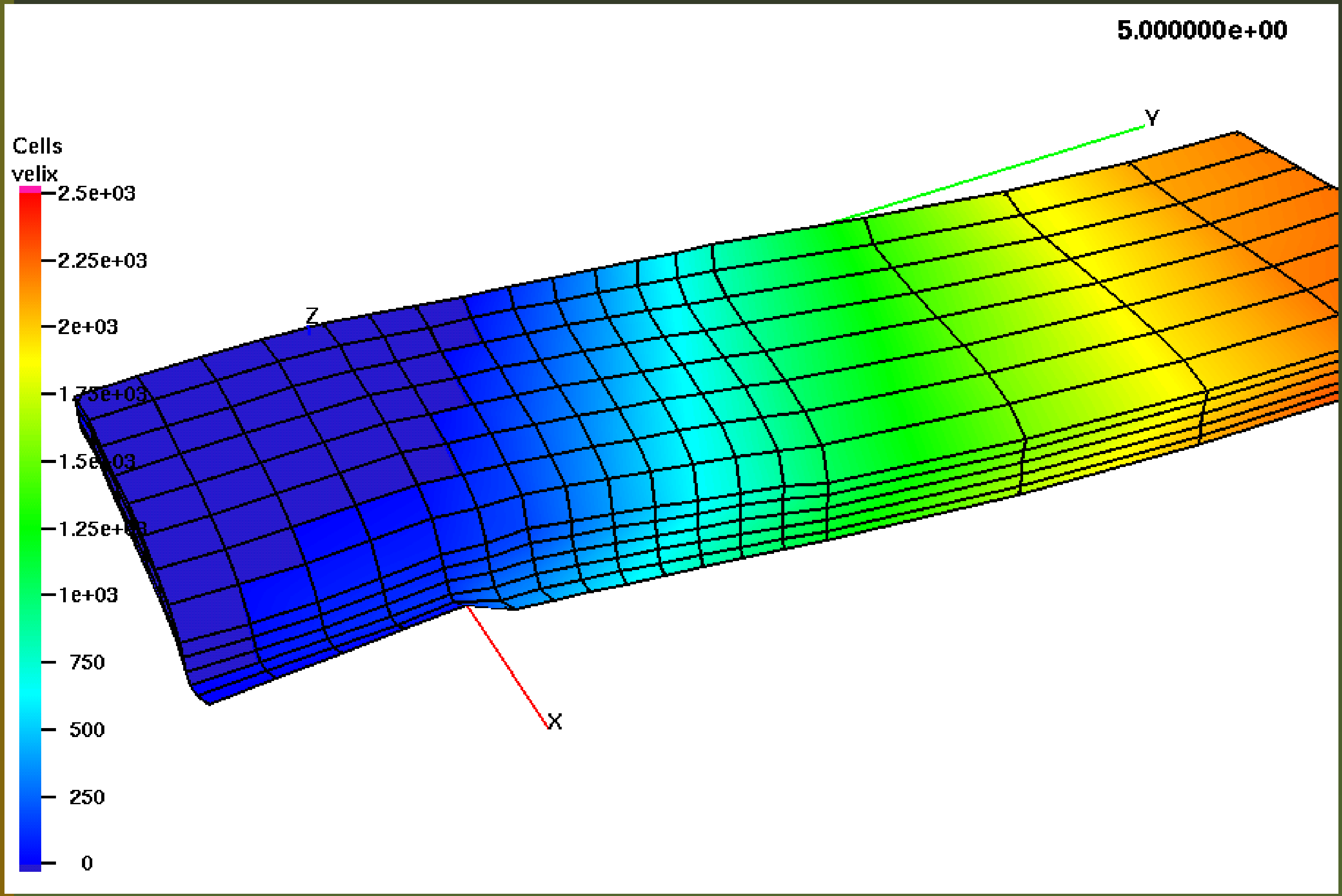

Motion events: the base

(A_1) Failure of plastic till at the base,
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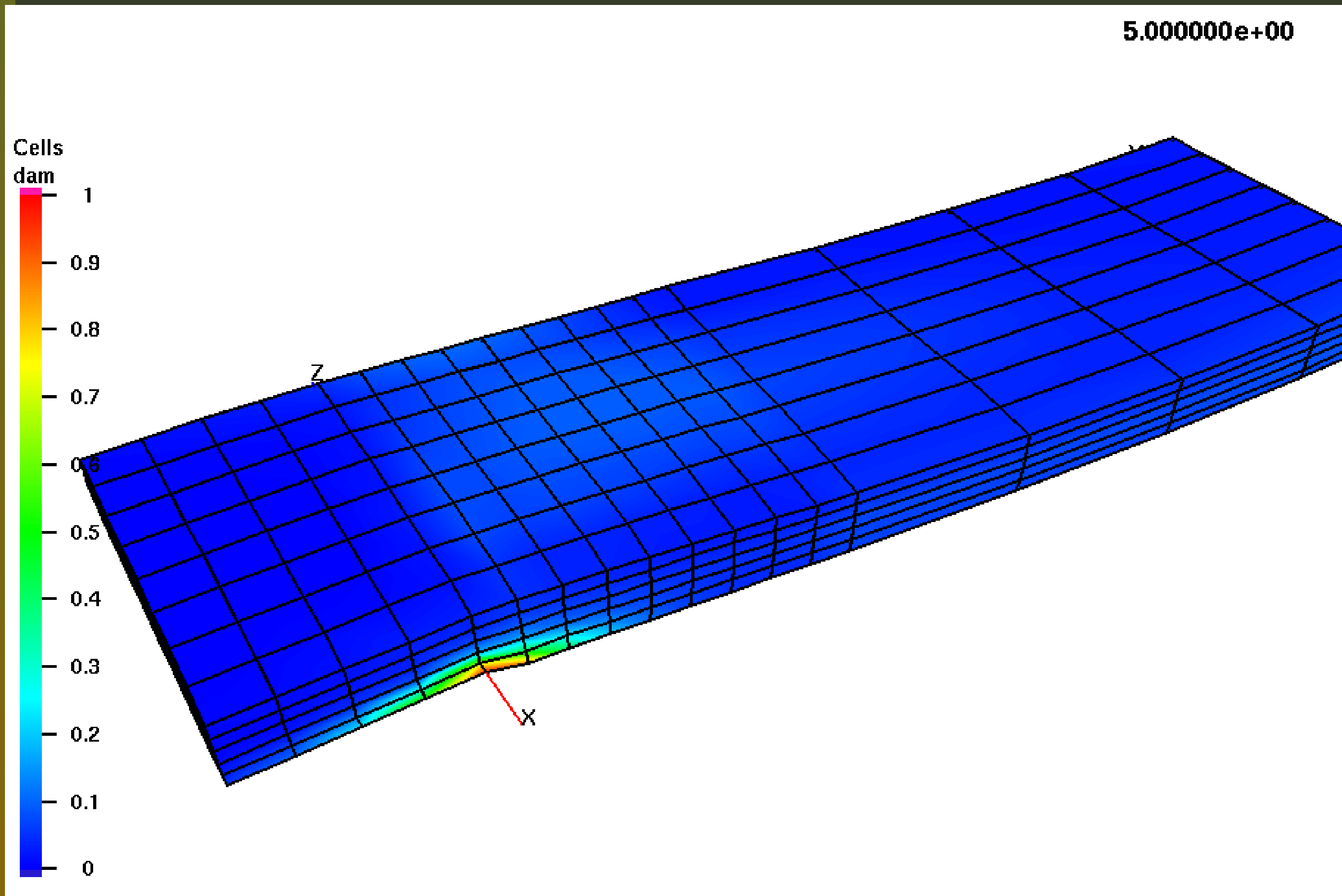
(A_2) Water-filled Yoffe-crack traveling along the ice-till interface (moving at subsonic velocity).

Motion events

(B) Damage evolution at the highly stressed margin:



Motion events

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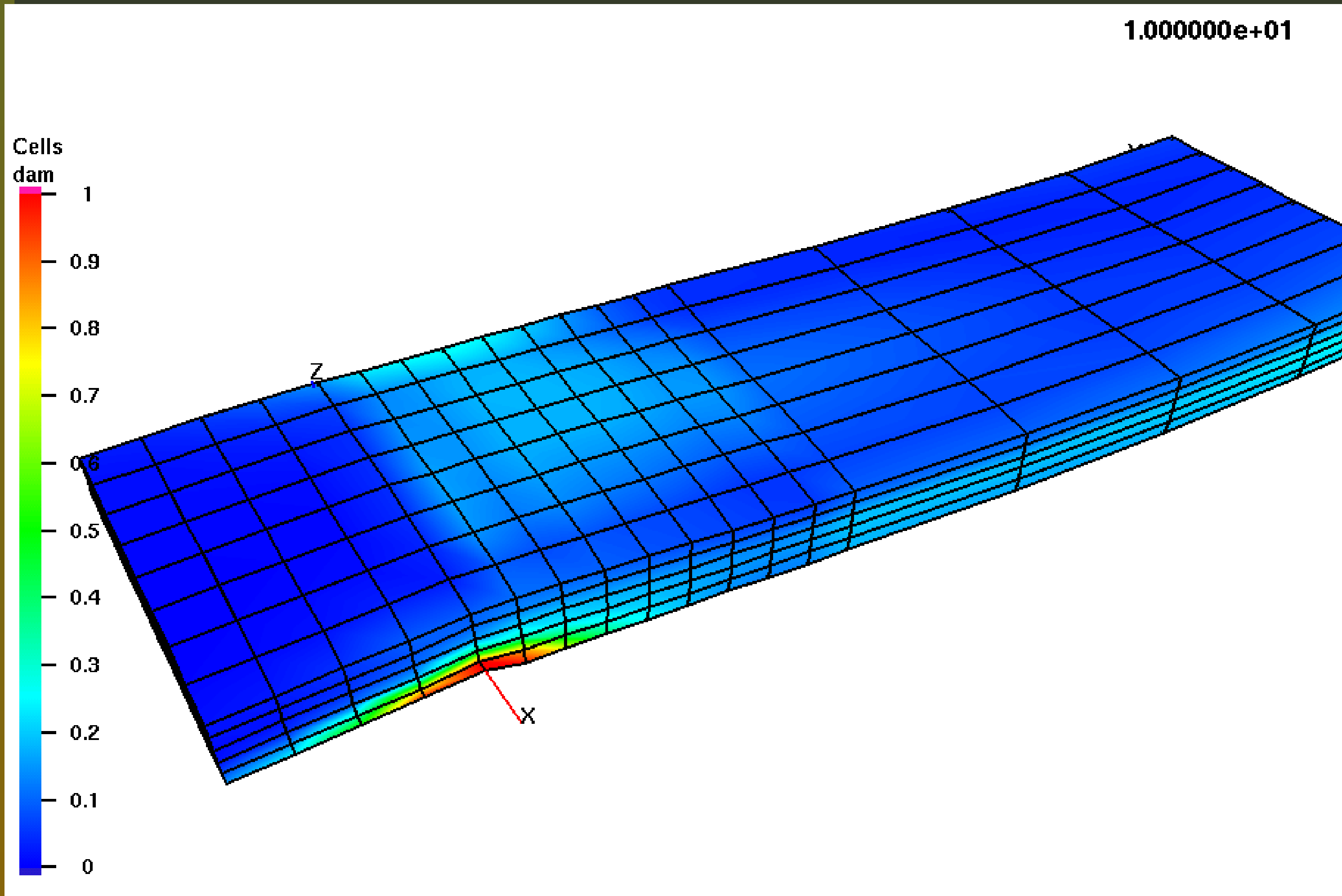

Motion events

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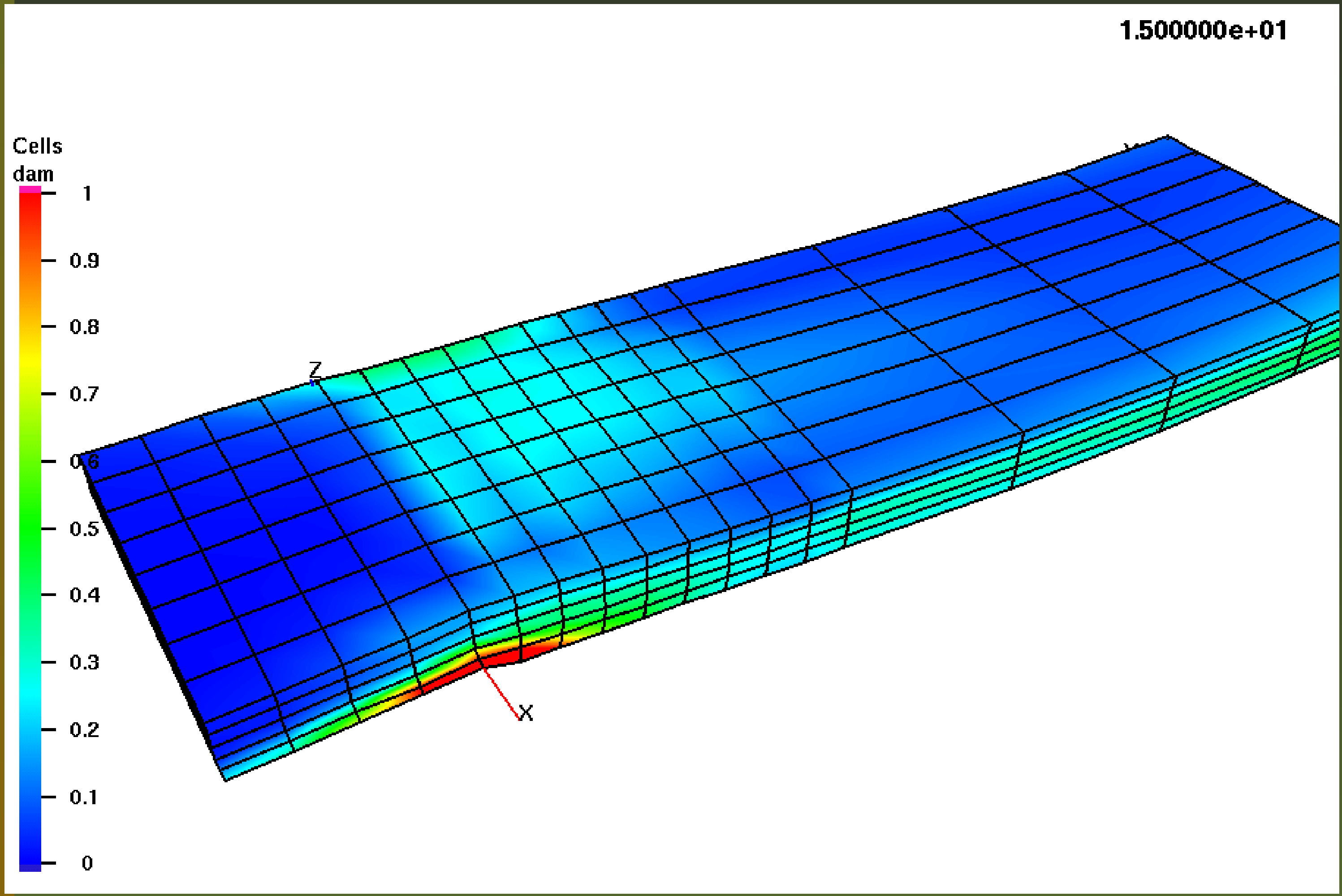

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Rapid loading of the base and plastic till failure.

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Rapid loading of the margins and cracking of the ice.

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Rapid loading of the base and plastic till failure.

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Rapid loading of the margins and cracking of the ice.

(D) Viscous flow, healing and damage reduction

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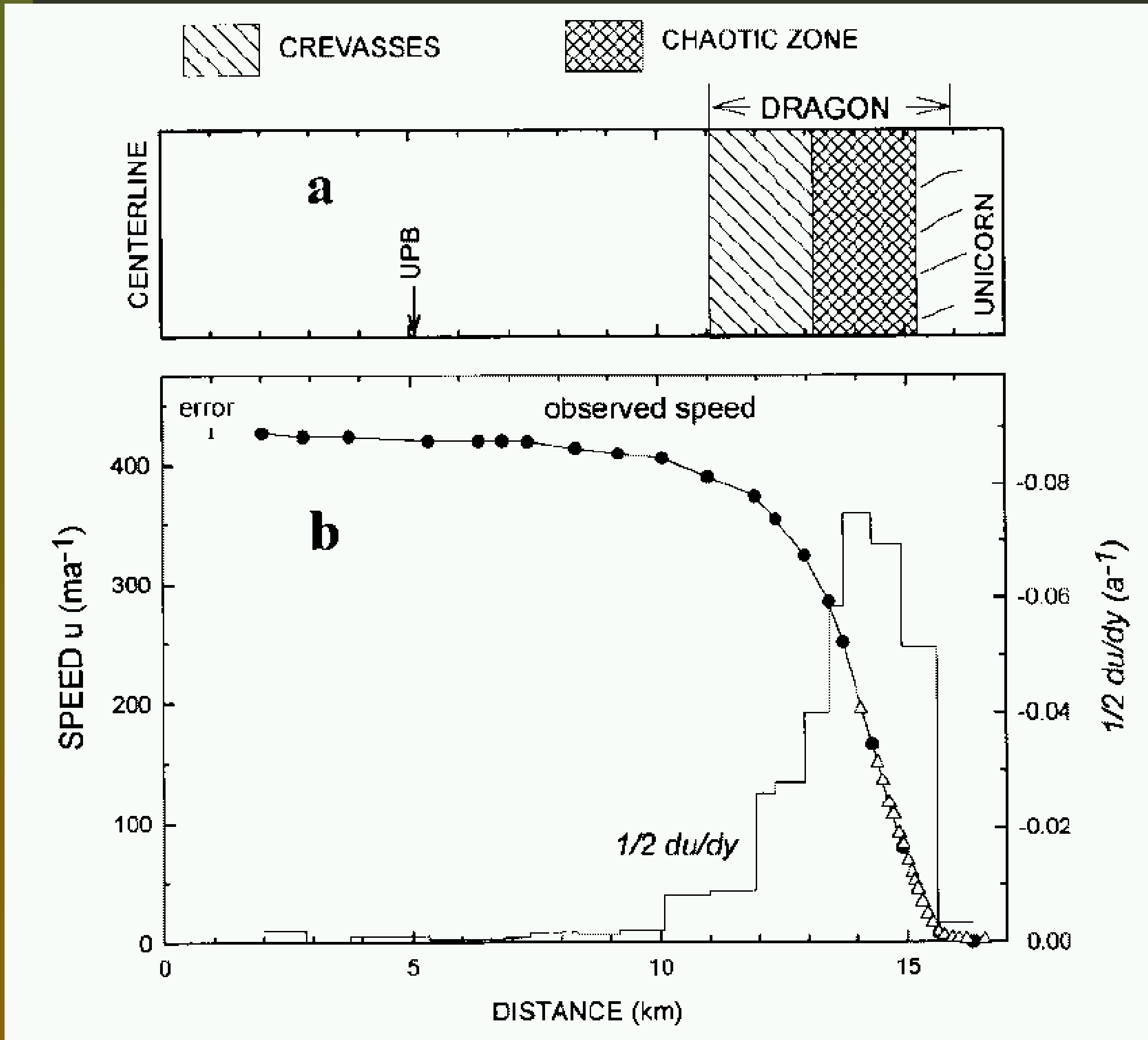
Ice stream margins are reminiscent of active faults. Damage mechanics has been successfully applied for

- prediction of fault location,
- prediction of margin migration,
- prediction of fault dynamics.

Velocity profile at margin (WIS)



(Echelmeyer et al., 1994)

Conclusions

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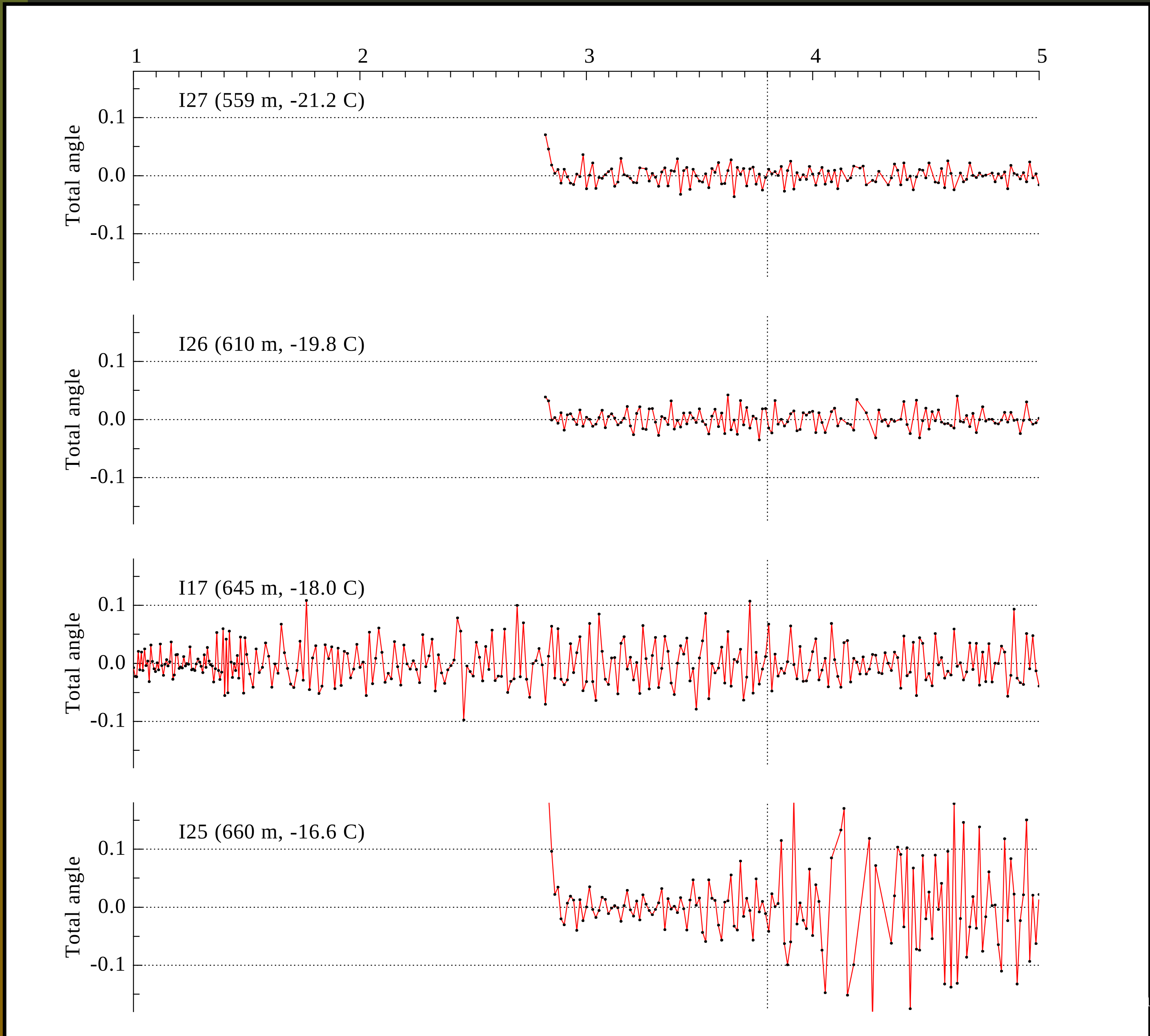
Main problems:

- Formulation of damage law
- Constrain the parameters

Processes at depth (Jakobshavn margin)



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